STATISTICAL ENTRY, DESCENT AND LANDING PERFORMANCE RECONSTRUCTION OF THE MARS PHOENIX LANDER

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The Phoenix Lander successfully landed on the surface of Mars on May 25, 2008. During the entry, descent and landing (EDL), the vehicle had instruments on-board that took sensed acceleration, angular rates and altimeter measurements. Additionally, satellites orbiting Mars during Phoenix's entry took range measurements of the descending vehicle. This paper will demonstrate the methodology used to reconstruct the trajectory information from observations from these various sensors. The paper will also present the reconstructed flight trajectory and the atmospheric profile sensed by the vehicle during its landing sequence.

Although Phoenix's trajectory has been reconstructed in the past by NASA, this current reconstruction differs from these past efforts due to the stochastic estimation techniques used to blend the different EDL data types. The estimation algorithm used in this case will be an Extended Kalman filter (EKF), which is adept at reconstructing states and their uncertainties for a non-linear problem. The stochastic nature of the reconstruction uses the inherent uncertainty in the measurement sensor data and propagates these values to quantify the uncertainties associated with the estimated trajectory and atmospheric parameters. The results of this reconstruction can thus allow a statistical comparison of the actual trajectory and atmosphere experienced by the vehicle and what was expected.

Moreover, the paper will analyze the aerodynamic performance of the vehicle through reconstruction of the aerodynamic coefficients of the vehicle throughout its trajectory. The primary dataset used in the aerodynamic reconstruction is the sensed acceleration measurements; thus, the aerodynamic and atmospheric uncertainties cannot be separated. Nevertheless, analysis of the estimated aerodynamic performance of the vehicle can be compared with predicted aerodynamic behavior, which in turn can lead to insight about crucial EDL events. One possible application of this performance analysis could be the during the parachute deployment phase, when one can compare the reconstructed aerodynamic coefficients with the predicted values. Additionally, Phoenix made atmospheric measurements shortly after it landed. Although these measurements do not exactly correspond with the timeline of the EDL events and measurements, these independent density, temperature and pressure measurements will be used to reconstruct the aerodynamic coefficients to see if the predicted behavior matched the estimated values. Since the atmospheric quantities are directly observable with this dataset, the uncertainties between the aerodynamics and atmospheric parameters can be separated.

The methodology and tools used to generate the results in this paper were created during the development of an EKF-based reconstruction tool by the Space Systems Design Laboratory at the Georgia Institute of Technology. This EKF tool has been used in the past to reconstruct the trajectory of Mars vehicles, such as Pathfinder and the Mars Exploration Rovers, and has been augmented to reconstruct the trajectory and atmospheric profile of the 2012 Mars Science Laboratory. This tool development effort has been supported by a NASA Research Announcement (NRA) award.